Probabilistic Risk Assessment Work Plan for the Newark Bay Study Area

JULY 17, 2017

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Acronyms

1-D	one-dimensional
AADD	annual average daily dose
ADAF	age-dependent adjustment factor
AOC	Administrative Order on Consent
AT	averaging time
BHHRA	baseline human health risk assessment
BW	body weight
CDF	cumulative distribution function
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	conversion factor
C_i	fish or crab concentration of chemical "i"
CL	cooking loss
COPC	chemical of potential concern
CTE	central tendency exposure
DF	dioxins and furans
DRA	deterministic risk assessment
ED	exposure duration
EDF	empirical distribution function
EF	exposure frequency
EFH	*Exposure Factors Handbook*
FI	fraction ingested from source
FS	feasibility study
HQ	hazard quotient
IR	ingestion rate
KM	Kaplan-Meier
LADD	lifetime average daily dose
NBC	Newark Bay Complex
NBSA	Newark Bay Study Area
NJORS	New Jersey Outdoor Recreation Survey
PCB	polychlorinated biphenyls
PDF	probability density function
PRA	probabilistic risk assessment
RAGS	USEPA's *Risk Assessment Guidance for Superfund*
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
SF	slope factor
TEQ	toxic equivalency
USEPA	United States Environmental Protection Agency

Executive Summary

Preliminary results of the Baseline Human Health Risk Assessment (BHHRA) for the Newark Bay Study Area (NBSA) indicate that potential excess cancer risks and noncarcinogenic hazards for an angler/sportsman may only slightly exceed generally acceptable levels (i.e., 1×10^{-4} and 1, respectively). To understand where the deterministic risk assessment (DRA) upper-bound point estimate will fall on a distribution of risk and hazards, a 1-dimensional probabilistic risk assessment (1-D PRA) of the fish and crab ingestion pathways is being proposed.

This work plan describes the set of equations used to calculate risks and hazards for the fish and crab ingestion pathways and details how distributions of variability will be defined for various exposure factors. **Table ES-1** lists the exposure factors to be treated as distributions in the PRA, along with a proposed definition for the distribution function or an approach to define the exposure factor distribution.

The PRA will be conducted using Oracle Crystal Ball with Monte Carlo sampling. The output of the PRA will be distributions of total lifetime excess cancer risks and noncarcinogenic hazards by chemical class and by all COPCs, for two separate PRA evaluations, which are termed PRA Evaluation 1 and 2. These two PRA evaluations are based on data from Veritas Evaluation 1 and 2, respectively. For Veritas Evaluation 1, Newark Bay fish and crab ingestion rates are based solely on Newark Bay sites in the 1995 Newark Bay Complex (NBC) Fishing and Crabbing Survey. In Veritas Evaluation 2, a more refined estimate of fish and crab ingestion was used to consider the overall angler population that takes fishing and crabbing trips to Newark Bay. Specific information pertaining to each of the two PRA evaluations is provided below:

- Fish Ingestion PRA Evaluation 1 — Fish ingestion risks and hazards will be calculated using Veritas Evaluation 1; an all-species fish ingestion rate distribution, along with a distribution for fish-tissue concentration that is based on all available fish-tissue data from the various species.
- Fish Ingestion PRA Evaluation 2 — Fish ingestion risks and hazards will be calculated using Veritas Evaluation 2; an all-species fish ingestion rate distribution along with a distribution for fish-tissue concentrations that is based on all available fish-tissue data from the various species.
- Crab Ingestion PRA Evaluation 1 — Risks and hazards for NBSA crab ingestion will be quantified using Veritas Evaluation 1; distributions of blue crab ingestion rates for blue crab hepatopancreas + muscle, and blue crab muscle only.
- Crab Ingestion PRA Evaluation 2 — Risks and hazards for NBSA crab ingestion will be quantified using Veritas Evaluation 2; distributions of blue crab ingestion rates for blue crab hepatopancreas + muscle, and blue crab muscle only.

Table ES-1. Summary of exposure factors to be distributed in the 1-D PRA

Distributed Parameter	Symbol	Units	Distribution Type	Values	Rationale/Reference
Fish Ingestion Rate	IRf	mg/kg	Veritas Eval 1: To be decided (TBD) Veritas Eval 2: Gamma	Veritas Eval 1: TBD Veritas Eval 2: Location - 0, 50th - 1.50, 95th = 13.84	Based on 1995 NBC survey; Veritas 2017
Crab Ingestion Rate	IRc	mg/kg	Veritas Eval 1: Gamma Veritas Eval 2: Gamma	Veritas Eval 1: 50th - 5.63, 90th - 41.24, 95th - 82.47 Veritas Eval 2: Location - 0, 50th - 0.86, 95th - 11.57	Based on 1995 NBC survey, 2000/2013 NJORS survey; Veritas 2017
COPC Concentration in fish/crab	Ci	mg/kg	TBD	TBD	Sampling data across 5-species of data will be used to fit distributions in for each chemical
Cooking Loss	CL	unitless	Empirical Distribution	TBD	To be based on USEPA 2000 Guide on Fish Advisory as well as recent literature
Exposure Duration	ED	years	Custom Distribution	Defined in Table 3	EFH 2011 Residential Occupancy Data
Body Weight	BW	kg	Custom Distribution	Defined in Table 4	NHANES 2011-12 Survey Data

1 Introduction

A Remedial Investigation/Feasibility Study (RI/FS) is being conducted by Glenn Springs Holdings, Inc., performing on behalf of Occidental Chemical Corporation (the successor to Diamond Shamrock Chemicals Company) for the Newark Bay Study Area (NBSA) in response to the Administrative Order on Consent (AOC) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA Index 02-2004-2010; U.S. Environmental Protection Agency [USEPA] 2004). The NBSA consists of Newark Bay and portions of the Hackensack River, Arthur Kill, and Kill van Kull.

Currently underway is a baseline human health risk assessment (BHHRA) that will address multiple potentially exposed populations, including the angler/sportsman, recreational user, and worker; and exposure pathways, including ingestion of fish and crab, dermal contact, incidental ingestion, and inhalation (via ambient air). Preliminary results of the deterministic risk assessment (DRA) indicate that potential excess cancer risks and noncarcinogenic hazards associated with fish and crab ingestion by an angler/sportsman may only slightly exceed generally acceptable levels (i.e., $1\text{x}10^{-4}$ and 1, respectively).

In a DRA, single values for exposure parameters are multiplied to determine cancer risk and noncarcinogenic hazard estimates for both central tendency exposure (CTE) and reasonable maximum exposure (RME). These exposure parameters are conservative to varying degrees, and according to USEPA, are often intended to "implicitly provide a margin of safety (i.e., more likely to overestimate risk than underestimate risk)" (USEPA, 2014a, p. 11). The resulting point estimate of RME risk and hazard represents some unknown level in the risk range (USEPA, 2001).

Probabilistic risk assessments (PRAs) comprehensively assess receptor health risks by using probability distributions to describe variability and/or uncertainty. As compared with a DRA, in a PRA, distributions of exposure parameters are multiplied in a probabilistic model to generate a probability distribution of results (e.g., cancer risk or non-cancer hazard) (see **Figure 1**).

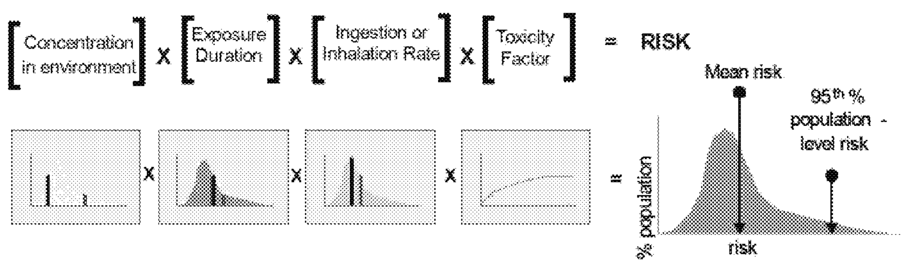

Figure 1. Graphic illustrating the concept of PRA (USEPA, 2014b)

The likelihood of exceeding a risk level of concern is determined quantitatively using PRA. The central tendency of the risk distribution (e.g., 50th percentile) can be used to quantify the CTE, and upper percentiles of the risk distribution (e.g., 90th and above percentiles) can represent the RME condition (USEPA, 2001). USEPA has developed several guidance documents on the use of PRA including:

1. USEPA. (2001) Risk Assessment Guidance for Superfund (RAGS): Volume III – Part A, Process for Conducting Probabilistic Risk Assessment. December 2001. EPA 540-R-02-002.

2. USEPA. (2014a) Risk Assessment Forum White Paper: Probabilistic Risk Assessment Methods and Case Studies. EPA/100/R-09/001A. Washington, D.C.: Risk Assessment Forum, Office of the Science Advisor, USEPA.

3. USEPA. (2014b) Probabilistic Risk Assessment to Inform Decision Making: Frequently Asked Questions. EPA/100/R-14/003. Washington, D.C. Risk Assessment Forum, Office of the Science Advisor, USEPA.

As noted by USEPA (2014b), PRA can enhance characterization of uncertainty and variability and help inform decisions (page 10 of the FAQ).

Consistent with the above guidance, a one-dimensional (1-D) PRA is being proposed herein to more realistically evaluate variability in potential exposures and associated health risks from the fish and crab ingestion pathways in the NBSA. Evaluation of this particular exposure pathway is similar to Case Study 5 presented in USEPA (2014a). This work plan describes the methods and assumptions that will be used to conduct the PRA. Other aspects of the BHHRA, including identification of chemicals of potential concern (COPCs) and toxicity criteria, will be the same in the PRA as those used in the DRA and are not discussed further herein. In accordance with USEPA's *Risk Assessment Guidance for Superfund, Volume 3: Part A* (RAGS; USEPA, 2001), the intent of this work plan is to establish a transparent and continuing dialogue with USEPA, so that the approach and outcomes of the PRA are consistent with the Agency's requirements.

In **Section 2**, the governing equations for the fish and crab ingestion pathway are defined, and probability distributions are presented for various exposure factors. **Section 3** details the methods for conducting the PRA, such as the software to be used and best practices to be implemented in the analysis.

2 Definitions for the Probabilistic Risk Assessment

The angler/sportsman is defined as an adult or adolescent catching and consuming a variety of fish (e.g., striped bass, American eel, etc.) or crab from the banks of the NBSA or from a boat on the NBSA, for recreational purposes. It is assumed that a child would not accompany adult anglers due to safety concerns, but would eat the fish or crab brought home.

2.1 Estimating Carcinogenic Risk and Noncarcinogenic Hazards from Fish and Crab Ingestion

The following **Equations 1–3** will be used to estimate excess carcinogenic risk and noncarcinogenic hazards posed to humans through exposure to COPCs in fish and crab. **Equation 1** results in a daily dose of chemical "i" (in mg/kg-day). When the averaging time for the carcinogenic risk evaluation is used (AT_{carc}), **Equation 1** represents a lifetime average daily dose ($LADD_i$) and this intake can be used along with **Equation 2** to determine lifetime excess cancer risk. When the averaging time for the noncarcinogenic evaluation is used (AT_{nc}), **Equation 1** represents an annual average daily dose ($AADD_i$), and this estimate of chemical intake can be used with **Equation 3** to estimate noncarcinogenic hazards.

(Eqn. 1)

$$\textbf{Daily Dose (mg/kg-day)}_i = \frac{\mathbf{IR \times FI \times C_i \times (1\text{-}CL) \times EF \times ED \times CF}}{\mathbf{BW \times AT_{nc\ or\ carc}}}$$

Where:

IR	=	Ingestion rate of fish or crab (g/day)
FI	=	Fraction from source (unitless)
C_i	=	Concentration of chemical "i" in fish or crab (mg/kg)
CL	=	Cooking loss (unitless)
EF	=	Exposure frequency (day/year)
ED	=	Exposure duration (years)
CF	=	Conversion factor (kg/g)
BW	=	Body weight (kg)
AT_{nc}	=	Averaging time (days) for the noncarcinogenic hazard evaluation is equivalent to exposure duration (in years) multiplied by 365 days/year
AT_{carc}	=	Averaging time (days) for the carcinogenic risk evaluation is equivalent to an average lifetime (in years) multiplied by 365 days/year.

Carcinogenic risk is estimated as the incremental probability of an individual developing cancer over a lifetime because of exposure at a site (e.g., Newark Bay) to a potential carcinogen, and this risk is a function of exposure and toxicity. Specifically, lifetime excess cancer risk is estimated as follows.

(Eqn. 2) $\mathbf{Lifetime\ Excess\ Cancer\ Risk_i = LADD_i \times SF_i \times ADAF}$

Where:

$LADD_i$	=	Lifetime average daily dose for chemical "i" (mg/kg-day)
SF_i	=	Slope factor (oral) for chemical "i" $(mg/kg\text{-}day)^{-1}$
ADAF	=	Age-dependent adjustment factor, if applicable.

Potential noncarcinogenic effects are evaluated by comparing exposure over a specified time period with a reference dose derived for a similar exposure period. This ratio of exposure to toxicity is referred to as a hazard quotient (HQ), which is calculated using the following equation.

(Eqn. 3) $\mathbf{HQ_i = AADD_i/RfD_i}$

Where:

$AADD_i$	=	Annual average daily dose for chemical "i" (mg/kg-day)
RfD_i	=	Reference dose for chemical "i" (mg/kg-day).

Total risks and hazards for the fish and crab ingestion pathways are calculated by summing across risks and hazards from each COPC.

The output of the PRA will be distributions of total cancer risks and noncarcinogenic hazards for the following evaluations (six in total):

- Fish Ingestion PRA Evaluation 1 — Fish ingestion risks and hazards will be calculated using Veritas Evaluation 1, all-species fish ingestion rate distribution (i.e., sample-based, current estimates of fish ingestion), along with a distribution for fish-tissue concentration that is based on all available fish-tissue data (i.e., American eel, striped bass, bluefish, summer flounder, and white perch).
- Fish Ingestion PRA Evaluation 2 — Fish ingestion risks and hazards will be calculated using Veritas Evaluation 2, all-species fish ingestion rate distribution (i.e., angling-population based, baseline estimates of fish ingestion) along with a distribution for fish-tissue concentration that is based on all available fish-tissue data (i.e., American eel, striped bass, bluefish, summer flounder, and white perch).
- Crab Ingestion PRA Evaluation 1 — Risks and hazards for NBSA crab ingestion will be quantified using Veritas Evaluation 1, blue crab ingestion rates for the following tissue data:
    - Blue crab hepatopancreas + muscle
    - Blue crab muscle only.
- Crab Ingestion PRA Evaluation 2 — Risks and hazards for NBSA crab ingestion will be quantified using Veritas Evaluation 2, blue crab ingestion rates for the following tissue data:
    - Blue crab hepatopancreas + muscle
    - Blue crab muscle only.

2.2 Variables to be Distributed in the 1-D PRA

The variables to be treated as distributions in the 1-D PRA include fish and crab ingestion rates, chemical concentrations for the contaminants of potential concern (COPC) in fish and crab, cooking loss, exposure duration, body weight, and averaging time for the noncarcinogenic evaluation. The following subsections for **Section 2.2** indicate either the specific probability distribution to be employed in the PRA, or an outline of the approach that will be taken for defining the probability distribution. To arrive at each of the specified distributions, a tiered review of literature was performed: (1) review of literature for exposure factors specific to Newark Bay, (2) USEPA risk assessments in the

Northeast (i.e., Hudson River, Housatonic River), and (3) recommendations from the USEPA's *Exposure Factors Handbook* (2011).

2.2.1 Fish and Crab Ingestion Rates (IR)

In June 2017, Veritas Economic Consulting (Veritas) prepared a memorandum reporting fish and crab ingestion estimates for Newark Bay. Veritas developed two sets of fish and crab consumption estimates using two different approaches (Veritas Evaluations 1 and 2). For the 1-D PRA, these two separate evaluations will be used to explore the impact of using Veritas Evaluation 1 vs. Veritas Evaluation 2 ingestion rates on the distributions of cancer risk and noncarcinogenic hazard. Brief descriptions of Veritas Evaluations 1 and 2 are presented in this section; more details on the methods used to develop Newark Bay fish and crab ingestion rates can be found in **Appendix B**. Both analyses describe ingestion rates that can be used for adult anglers fishing and crabbing in NBSA. For adolescent anglers and children consuming fish and crab from the NBSA, the standard USEPA factor of two-thirds and one-third will be applied to the adult ingestion rate, respectively. These factors have been previously reviewed by USEPA as part of its review of RAGS Table 4.

2.2.1.1 Veritas Evaluation 1

Newark Bay fish and crab ingestion rates in Veritas Evaluation 1 are based solely on Newark Bay sites in the 1995 Newark Bay Complex (NBC) Fishing and Crabbing Survey. (Note that the data from the 1999, 2002, and/or 2005 NBC Fishing and Crabbing Surveys were not available to Veritas at the time of this evaluation, but can be incorporated if provided by USEPA.) This survey asked respondents how often they ate fish or crab caught from the NBC (i.e., every day, 2–3 times/week, once per week, twice per month, once per month, or less than once per month) and the serving size of crab or fish for a single meal. Using an assumption for consuming months per year (i.e., 1–6 months/year with an average of 4 months), Veritas developed the statistics presented in **Table 1** for fish and crab consumption per day for all anglers and for consuming anglers.

Table 1. Fish and crab ingestion rates for Newark Bay anglers for Veritas Evaluation 1 (Veritas, 2017)[a]

Species Scenario	Angling Population Scenario	Anglers	Consumption (g/day)				
			Mean	Median	90th	95th	99th
All Fish Species	All Anglers	57	0.34 (0.06-1.31)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	1.14 (0.58-1.65)
	Fish Consumers	**2**	**9.60 (1.67-37.46)**	**1.14 (0.58-1.65)**	**18.06 (2.64-73.81)**	**18.06 (2.64-73.81)**	**18.06 (2.64-73.81)**
Blue crab	All Anglers	57	9.53 (2.53-20.68)	0.86 (0.23-1.87)	24.19 (6.42-52.47)	41.48 (11.01-89.95)	82.95 (22.01-179.91)
	Blue crab Consumers	**29**	**18.74 (4.97-40.67)**	**5.67 (1.50-12.29)**	**41.24 (11.37-83.91)**	**82.95 (22.01-179.91)**	**124.43 (33.02-269.86)**

[a] Bolded entries will be used in the 1-D PRA.

The mean and various perecentiles for fish and crab consumption can be seen in **Table 1** along with the 90-percent confidence interval for each of these estimates. Bolded values in **Table 1** indicate the angling population scenario of interest that will be used in the 1-D PRA for PRA Evaluation 1 (fish- or blue-crab-consuming anglers only). To represent the statistics presented for PRA Evaluation 1, ingestion rates will be distributed as follows:

- IR_{crab}: Gamma (50^{th} = 5.67, 90^{th} = 41.24, 95^{th} = 82.95 g/day).

The distribution type recommended above (i.e., gamma) (and in the subsequent section for PRA Evaluation 2) is based on a review of various distributions in Crystal Ball. For each scenario, three summary statistics were selected to define a variety of distributions (e.g., lognormal, gamma, normal, beta, max extreme). Summary statitics for the fitted distribution were then compared to other statisics presented in the Veritas analysis. For example, defining blue crab consumers using a gamma distribution with the above specifications, estimates a mean consumption of 18.92 g/day; that is within 1% of the mean presented above, 18.74 g/day.

Only two respondents in the 1995 NBC fishing and crabbing survey reported consuming fish. With such few data points, a distribution is currently not being recommended for fish-consuming anglers in Veritas Evaluation 1. Should additional data be provided by the USEPA to include into this analysis for Newark Bay sites, a distribution can be developed for fish-consuming anglers.

The ingestion rates presented in Veritas Evaluation 1 represent only the interviewed survey respondents (n=57) and are not necessarily representative of the entire angling population in Newark Bay. Additionally, the statistics represent survey answers at the time of administration with the fish advisory already in place. Therefore, while the values are useful for risk assessment, these estimates represent current fish and crab ingestion rates and are not considered to be true baseline (pre-fish advisory) ingestion rates (Veritas, 2017).

2.2.1.2 Veritas Evaluation 2

A more refined estimate of fish and crab ingestion was used in Veritas Evaluation 2 to consider the overall angler population that takes fishing and crabbing trips to Newark Bay. For this analysis, two components were combined with the 1995 NBC Fishing and Crabbing Survey data: ZIPcode-level population data from the five-county area (Union, Essex, Hudson, Bergen, and Passaic), and a function of angler trip preference developed from the 2000 and 2013 New Jersey Outdoor Recreation Survey (NJORS) (Veritas, 2017). The preference function models how anglers decide where to go fishing and how many trips they take based on various model descriptors, such as distance from home, expected catch, amenities, industrialization, crime rates, etc. Additionally, the use of the 2013 NJORS survey allows for development of increased baseline consumption rates for times when the fish advisory was not in effect (Veritas, 2017).

Bolded values in **Table 2** indicate the angling population scenario of interest that will be used in the 1-D PRA for PRA Evaluation 2 (fish- or blue-crab-consuming anglers, baseline consumption). Veritas Evaluation 2 ingestion rates will be distributed as follows to closely approximate the statistics present in **Table 3**:

- IR_{fish}: Gamma (location = 0, 50^{th} = 1.50, 95^{th} = 13.84 g/day)

- IR_{crab}: Gamma (location = 0, 50^{th} = 0.86, 95^{th} = 11.57 g/day).

Table 2. Fish and crab ingestion rates for Newark Bay anglers for Veritas Evaluation 2 (Veritas, 2017)

Species Scenario	Angling Population: Scenario	Angling Population: Number of Anglers	Angling Population: Trips	Risk Estimate Scenario	Consumption (g/day): Mean	Consumption (g/day): Median	Consumption (g/day): 90th	Consumption (g/day): 95th	Consumption (g/day): 99th
All Fish Species[a]	All Anglers	3,550	21,130	Baseline	1.82 (0.41-5.10)	0.24 (0.10-0.70)	5.11 (1.20-14.22)	9.46 (2.00-26.63)	22.50 (4.99-69.07)
		2,439	12,190	Current	1.08 (0.24-3.12)	0.00 (0.00-0.00)	3.13 (0.70-8.86)	5.43 (1.20-15.51)	12.92 (2.80-37.65)
	Fish Consu-mers	**1,825**	**14,599**	**Baseline**	**3.54 (0.81-9.87)**	**1.50 (0.40-4.22)**	**9.24 (2.00-26.44)**	**13.84 (3.09-40.16)**	**28.04 (6.19-77.46)**
		1,176	7,827	Current	2.22 (0.54-6.38)	1.08 (0.30-3.12)	5.53 (1.30-15.70)	8.35 (1.90-24.17)	16.53 (3.80-48.69)
Blue crab	All Anglers	3,550	21,130	Baseline	1.38 (0.33-3.72)	0.12 (0.00-0.30)	3.80 (0.90-9.13)	7.58 (1.69-20.03)	19.17 (4.64-56.69)
		2,439	12,190	Current	0.69 (0.19-1.46)	0.00 (0.00-0.00)	1.98 (0.60-4.11)	3.45 (0.10-7.30)	8.24 (2.30-17.62)
	Blue crab Consu-mers	**1,791**	**14,332**	**Baseline**	**2.70 (0.72-7.20)**	**0.86 (0.30-1.92)**	**7.45 (1.79-19.55)**	**11.57 (2.69-30.73)**	**23.18 (5.76-63.83)**
		1,169	7,776	Current	1.42 (0.46-2.99)	0.68 (0.2-1.41)	3.50 (1.10-7.31)	5.31 (1.60-11.11)	10.59 (3.00-22.05)

[a]All fish species ingestion rates include American eel, bluefish, striped bass, and white perch.

2.2.2 *Concentration in Fish or Crab (C_i)*

Appendix A contains a preliminary draft list of the COPCs that will be assessed in the BHHRA and the 1-D PRA for the NBSA. Of note is that this list is still draft and will be finalized as a part of the BHHRA. Fish and crab sampling data from three sampling events conducted in Newark Bay (fall 2014, spring/summer 2015, and spring 2016) under Phase III of the RI (Tierra, 2016) will be used to define probability distributions for each of the COPCs.[1]

Fish-tissue concentrations in this data set are presented for whole body, fillet, and liver. Consistent with the BHHRA, potential risk and health hazards will be evaluated using chemistry data from only individual and composite fish fillet samples (Tierra, 2016), which are available for the following species:

1. American eel
2. Bluefish
3. Striped bass
4. Summer flounder
5. White perch.

Distributions for each of the COPCs will be defined using data from all five species. With roughly 18 samples per species, distributions for each of the COPCs in fish will be derived using a sample size of approximately 90 samples.

Blue crab samples are presented in the sampling data as whole carcass, hepatopancreas, and muscle. For the PRA, crab tissue will be evaluated as two scenarios: hepatopancreas + muscle and muscle only. The combined hepatopancreas + muscle data set is calculated according to **Equation 4**, below, using pairs of hepatopancreas and muscle concentrations. Hepatopancreas and muscle concentrations are considered "paired" if taken from the same location.

(Eqn. 4) $$\mathbf{C_{H+M} = (C_H \times 0.26) + (C_M \times 0.74)}$$

Where:

C_{H+M} = Concentration in blue crab hepatopancreas and muscle tissues (mg/kg)
C_H = Concentration in blue crab hepatopancreas (mg/kg)
C_M = Concentration in blue crab muscle tissues (mg/kg).

Equation 4, developed by Arcadis, is based on tissue weight data for 34 individual crabs reported in Newark Bay Phase III data and excludes carcass weight.[2]

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1 Fish and crab sampling data are located in a Microsoft Access database titled "Biota-Sediment_Database_081916.accdb."

2 The fractional weights for each tissue type are as follows: 0.27—carcass, 0.19—hepatopancreas, and 0.54—muscle. Excluding carcass data results in increased fractional portions for hepatopancreas and muscle (0.26 and 0.74, respectively).

Using the Oracle® Crystal Ball v11.1 distribution fitting module, various distributions will be tested on the COPC-specific sample data, and the recommended distribution will be selected to represent C_i as ranked by the following goodness-of-fit statistics: Anderson-Darling, Kolmogorov-Smirnov, and Chi-square. If the underlying data are not represented adequately by any of the tested distributions, an empirical distribution function of the underlying data will be employed. Trucation of distributions will be considered if the recommended distributions yield unrealistic or impossible values as a result of unintended statistical artifacts.

As an example, **Figure 2** below shows the results of the distribution fitting procedure in Crystal Ball for the fish concentration of Kaplan-Meier Toxic Equivalency for Dioxins and Furans (KM TEQ[3] DF). The recommended distribution for KM TEQ DF across all species of fish is a gamma distribution described by the Location = 0, Scale = 1×10^{-5}, and Shape = 0.74223. This distribution has a median of 4.33×10^{-6} mg/kg, a mean of 6.99×10^{-6} mg/kg, and a 95% value of 2.26×10^{-5} mg/kg.

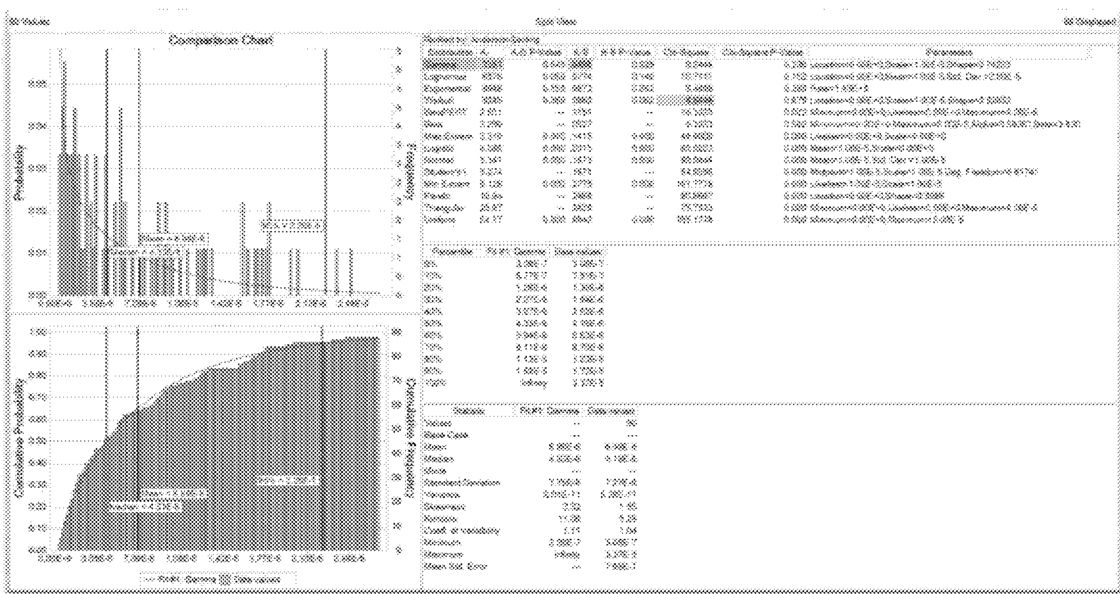

Figure 2. Example of distribution fitting in Crystal Ball for fish-tissue concentrations of KM TEQ DF (mg/kg)

Similarly, **Figure 3** shows the distribution fitting procedure for fish-tissue concentrations of KM TEQ polychlorinated biphenyls (PCBs). For this COPC, the recommended distribution is a lognormal distribution defined by location = 0, Mean = 1.0×10^{-5}, and Standard Deviation = 1.0×10^{-5}. The distribution has a median, mean, and 95% of 2.25×10^{-5}, 5.2×10^{-5}, and 1.89×10^{-5} mg/kg, respectively.

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[3] KM TEQ based on USEPA Advanced KM TEQ Calculator (V9.1, July 31, 2014).

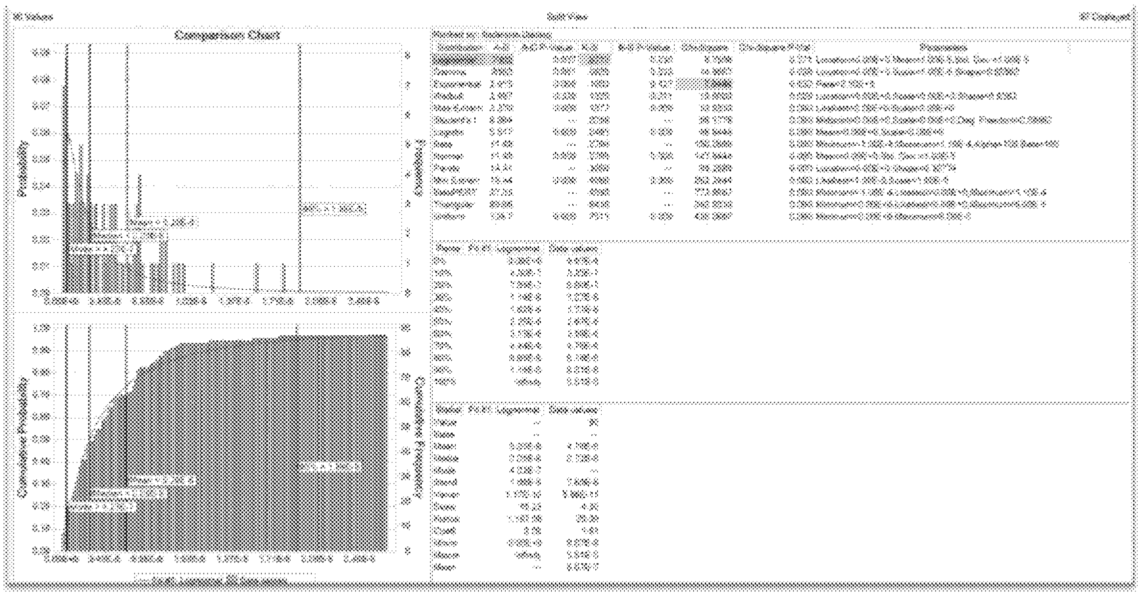

Figure 3. Example of distribution fitting in Crystal Ball for fish-tissue concentrations of KM TEQ PCB (mg/kg)

2.2.3 Cooking Loss

Loss of chemicals due to cooking is a known phenomenon for hydrophobic chemicals and can have a significant impact on the exposure dose from fish and crab consumption. Cooking-loss data presented in the USEPA Guide on Fish Advisories range from as low as 0 to 78%, with a mean of 32% for PCBs, and for dioxins, range from 37% to 80% cooking loss, with a mean value of 54% for dioxins (USEPA, 2000).

Cooking loss will be incorporated into the 1-D PRA as an empirical distribution function (EDF) to represent the values seen in literature. This EDF will include the studies reviewed in the 2000 USEPA Guide on Fish Advisories, but will be augmented to also include any recent literature published on cooking loss. Any recent papers that are identified will be submitted to USEPA for review. Only chemical reduction values associated with a cooking activity will be incorporated into the distribution (e.g., skinning and trimming chemical reduction values will be ignored).

2.2.4 Exposure Duration and Averaging Time

A distribution for exposure duration will be included only for the adult angler evaluation (adolescent and child exposure durations will be held constant at 12 and 6 years, respectively). Because angler survey data on how long anglers have fished in NBSA is not available, this analysis will conservatively assume residential occupancy period data as a proxy for angler exposure duration. Specifically, a custom distribution of percentiles from the USEPA *Exposure Factors Handbook* (EFH) 2011 will be used to define the exposure duration distribution (see **Table 3**).

Table 3. Custom probability distribution for exposure duration for an adult angler based on residential occupancy period (USEPA, 2011)

Res Occupancy Period (ROP)	Yrs
5th percentile	2
10th percentile	2
25th percentile	4
50th percentile	9
75th percentile	16
90th percentile	26
95th percentile	33
98th percentile	41
99th percentile	47
99.5th percentile	51
99.8th percentile	55
99.9th percentile	59
Max	87

As shown in **Equation 1** above, exposure duration is essentially considered only in the carcinogenic evaluation. For the noncarcinogenic equation, averaging time is equivalent to exposure duration distribution multiplied by days; therefore, the exposure duration term in the numerator cancels the exposure duration term in the denominator.

2.2.5 Body Weight

Distributions for body weight are proposed to be based on a data analysis of male and female respondents to the National Health and Nutrition Examination Survey (NHANES) conducted for the 2011–12 survey cycle (CDC, 2012). The analysis of this dataset was performed in R using the *survey* analysis package, which incorporate survey weights to obtain percentile statistics of body weight for the specific age groups of interest (as shown in **Table 4**).

Table 4. Custom probability distributions for body weight for an adult angler, adolescent angler, and child (CDC, 2012)

Statistic	Body Weight Percentiles from NHANES 2011-12		
	BW(kg) - Ages 1 to 6	BW(kg) - Ages 7 to 18	BW(kg) - Ages 18+
Mean	17.6	53.6	81.7
SE	0.1	0.9	0.5
0%	8.6	17.2	29.1
1%	9.6	20.7	46.1
5%	10.7	24.1	53.6
10%	11.6	27.8	58.0
15%	12.4	30.9	61.4
20%	13.1	33.5	64.1
25%	14.0	37.0	66.6
30%	14.5	40.4	69.1
35%	15.1	43.5	71.7
40%	15.5	46.1	74.4
45%	16.1	49.0	76.8
50%	16.6	50.8	79.1
55%	17.3	53.7	81.4
60%	18.1	55.6	83.7
65%	18.8	58.7	86.5
70%	19.5	61.9	89.5
75%	20.2	65.6	92.7
80%	21.3	71.0	96.9
85%	22.4	76.8	102.0
90%	23.8	81.8	107.9
95%	26.8	92.4	119.0
99%	33.7	118.6	144.9
100%	45.1	180.6	216.1

3 Probabilistic Risk Assessment Methods and Reporting

3.1 Simulation Report

The 1-D PRA will be conducted using Oracle Crystal Ball version 11.1. Distributions will be defined as described in **Section 2.2**, and forecasts of exposure parameters and risks and hazards (aggregated by chemical class and on a total basis) will be followed throughout the simulation. Sampling will be conducted using Monte Carlo, the most common numerical technique for PRA (USEPA, 2001). Numerical stability will be evaluated, as prescribed in RAGS 3 Part A, by implementing precision control limits and by verifying the number of iterations is sufficient to ensure stability. In particular, numeric stability will be evaluated and reported for the 50th and the 95th percentile values of the risk and hazard distributions, which will be used to represent typical (CTE) and upper-bound exposure conditions (RME). Typically, 10,000 iterations should be sufficient to produce stable numerical results. Stability should not be an issue for relatively simple models such as what is being proposed in this work plan.

3.2 Reporting Results and Sensitivity Analysis

The results of the PRA will be presented in both tabular and graphical formats as part of the BHHRA report. The 50th and the 95th percentiles of the distributions of carcinogenic risk and noncarcinogenic hazards for each of the scenarios listed in **Section 2.1** will be reported. Risk and hazard cumulative distribution functions (CDFs) and probability density functions (PDFs) for chemicals that contribute the most to risk and hazard (e.g., dioxins, PCBs, etc.) will also be graphically reported in the results (see examples in **Figure 4**). Additionally, results of the deterministic BHHRA will be evaluated in the context of the PRA risk range, to communicate where the point estimates of CTE and RME fall on the risk distribution.

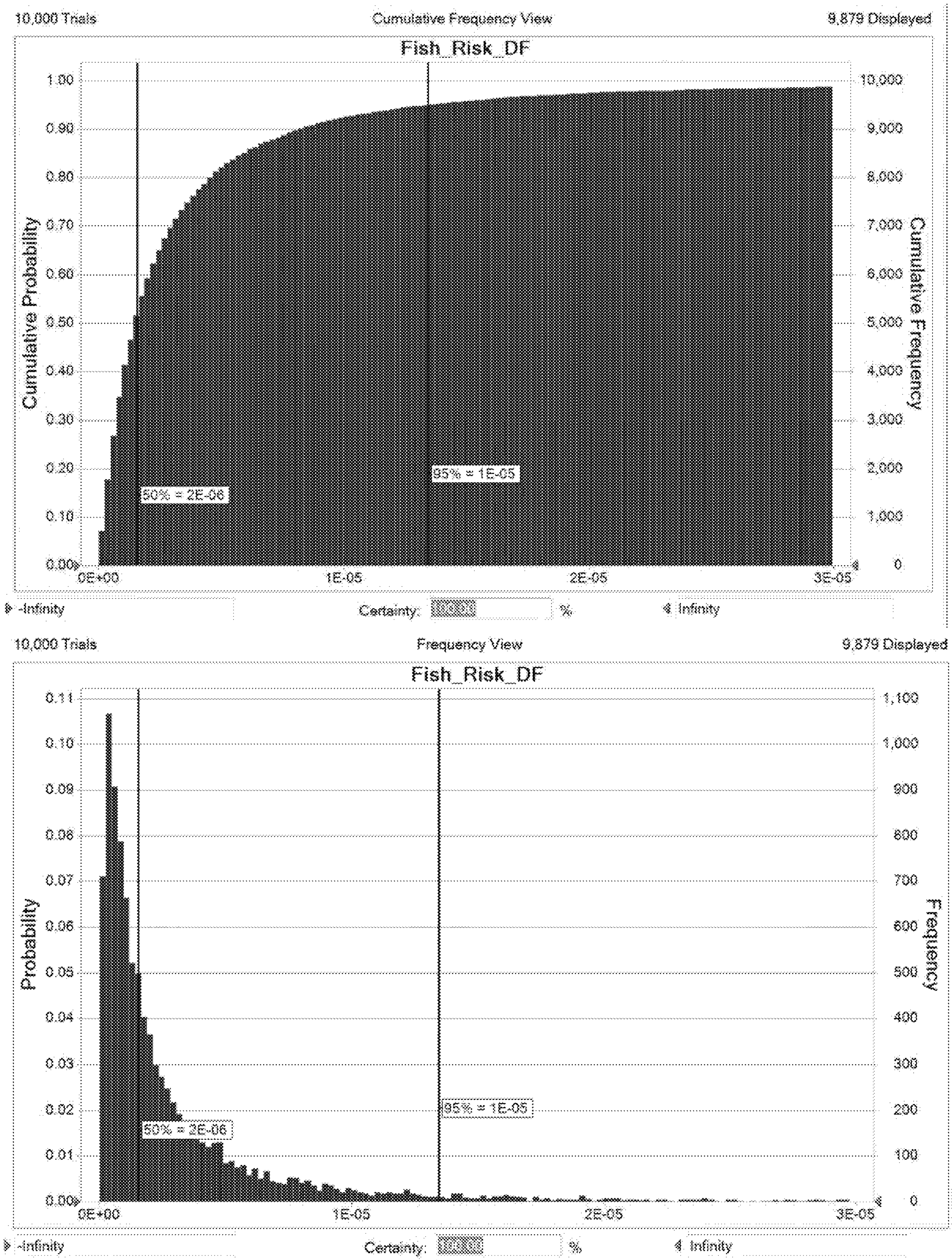

Figure 4. Example cumulative distribution function (CDF) and probability density function (PDF) graphs from Oracle Crystal Ball

For each of the chemical class aggregations, sensitivity analyses will be conducted to determine which of the input variables contribute most to the variance in the risk and hazard distributions. Crystal Ball computes rank correlation coefficients between every exposure assumption and the computed risk/hazard estimate while the simulation runs. To estimate a factor's contribution to variance, Crystal Ball squares the rank correlation coefficients and normalizes them to 100% (Oracle, 2009). Example sensitivity tornado charts produced by Crystal Ball are shown in **Figure 5** for a hypothetical risk assessment for the fish ingestion pathways.

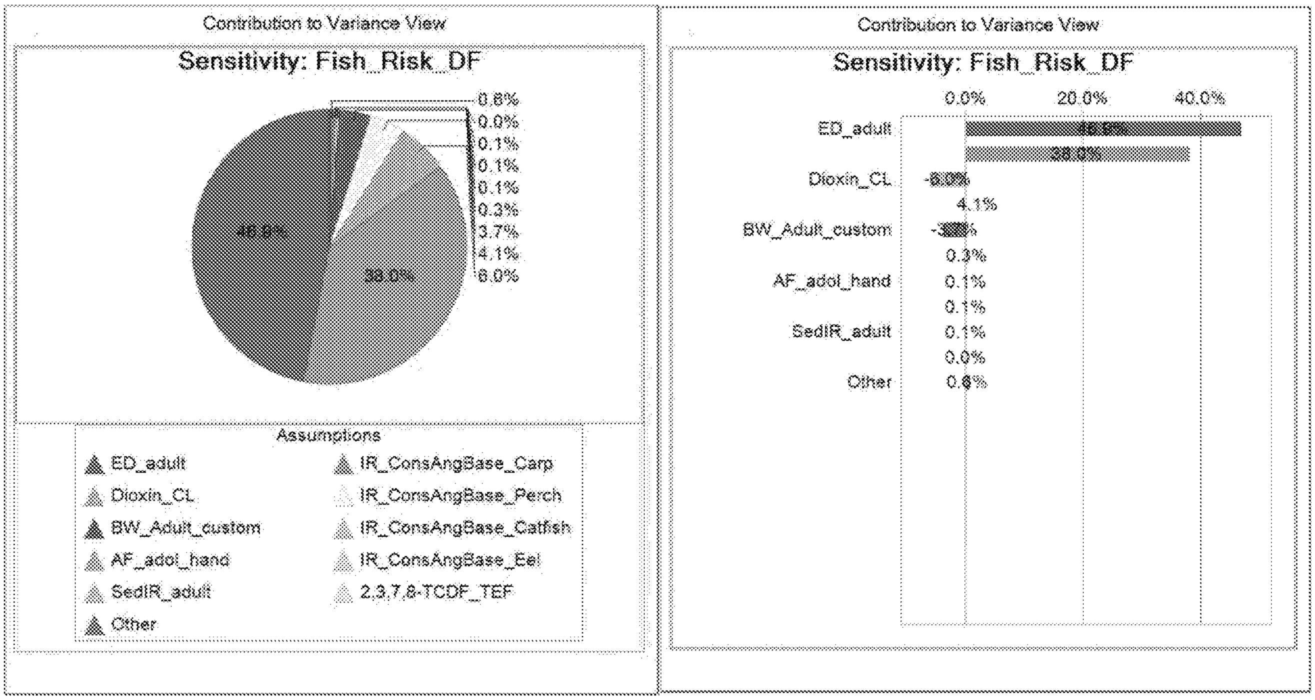

Figure 5. Example sensitivity charts produced by Crystal Ball to evaluate parameter contribution to variance

4 Summary and Schedule

The 1-D PRA proposed herein can provide additional information about the variability in potential exposures and associated health risks from the fish and crab ingestion pathways in the NBSA. Several proposed exposure factor and chemical-specific distributions are included in this work plan along with identification of available data (i.e., data from the 2002 and 2005 NBC fishing and crabbing survey) that could be used to help improve the PRA.

The anticipated next steps are USEPA review, submittal of a revised work plan, and implementation of the approved PRA Work Plan.

5 References

CDC. 2011–12. National Center for Health Statistics (NCHS), National Health and Nutrition Examination Survey Data. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Hyattsville, MD.

Oracle. 2009. Crystal Ball user's guide, 11.1.1.3.00. https://docs.oracle.com/cd/E12825_01/epm.111/cb_user.pdf.

Tierra. 2017. Newark Bay Study Area Fish Data Report. Tierra Solutions, Inc., February, Revision 1.

USEPA. 2000. Guidance for assessing chemical contaminant data for use in fish advisories. Volume 2, Risk assessment and fish consumption limits. 3rd Edition. EPA 823-B-00-008. U.S. Environmental Protection Agency.

USEPA. 2001. Risk assessment guidance for Superfund (RAGS): Volume III – Part A, Process for conducting probabilistic risk assessment. EPA 540-R-02-002. U.S. Environmental Protection Agency.

USEPA. 2004. Administrative Order on Consent for Remedial Investigation and Feasibility Study, Newark Bay Study Area USEPA Index No. CERCLA-02-2004-2010. Including all attachments, amendments, and updates.

USEPA. 2011. Exposure factors handbook: 2011 Edition. EPA/600/R-09/052F. U.S. Environmental Protection Agency, National Center for Environmental Assessment, Washington, DC. Available from the National Technical Information Service, Springfield, VA, and online at http://www.epa.gov/ncea/efh.

USEPA. 2014a. Risk assessment forum white paper: Probabilistic risk assessment methods and case studies. EPA/100/R-09/001A. U.S. Environmental Protection Agency, Risk Assessment Forum, Office of the Science Advisor, Washington, DC.

USEPA. 2014b. Probabilistic Risk Assessment to Inform Decision Making: Frequently Asked Questions. EPA/100/R-14/003. Washington, D.C. Risk Assessment Forum, Office of the Science Advisor, USEPA.

Veritas. 2017. Newark Bay fish and crab ingestion estimates. Veritas Economic Consulting, June 6 [see Appendix B].

APPENDIX A

Preliminary COPC List for the Fish/Crab Ingestion Pathway

Table A-1. Draft Preliminary Chemicals of Potentical Concern (COPC) for the fish and crab ingestion pathways

Chemical of Potential Concern (COPC)
Dioxin-like Compounds
1,2,3,4,6,7,8-HpCDD
1,2,3,4,6,7,8-HpCDF
1,2,3,4,7,8,9-HpCDF
1,2,3,4,7,8-HxCDD
1,2,3,4,7,8-HxCDF
1,2,3,6,7,8-HxCDD
1,2,3,6,7,8-HxCDF
1,2,3,7,8,9-HxCDD
1,2,3,7,8,9-HxCDF
1,2,3,7,8-PeCDD
1,2,3,7,8-PeCDF
2,3,4,6,7,8-HxCDF
2,3,4,7,8-PeCDF
2,3,7,8-TCDD
2,3,7,8-TCDF
KM TEQ DF
KM TEQ PCB
OCDD
OCDF
PCB-105
PCB-114
PCB-118
PCB-123
PCB-126
PCB-156
PCB-167
PCB-169
PCB-189
PCB-77
PCB-81
PCBs
Total Non-DL PCBs

Table A-1 (Continued). Draft Preliminary Chemicals of Potentical Concern (COPC) for the fish and crab ingestion pathways

Chemical of Potential Concern (COPC)
PAHs
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Dibenzo(a,h)anthracene
Indeno(1,2,3-cd)pyrene
Pesticides & Organics
2,4'-DDE
2,4'-DDT
4,4'-DDD
4,4'-DDE
4,4'-DDT
Alpha-Chlordane
Benzaldehyde
Benzidine
Dieldrin
Heptachlor Epoxide
Hexachlorobenzene
Mirex
Nonachlor, trans-
Oxychlordane
Pyridine
cis-Nonachlor
trans-Chlordane
trans-Heptachlor Epoxide
Inorganics
Arsenic
Beryllium
Cadmium
Cobalt
Copper
Iron
Lead
Manganese
Mercury
Methyl Mercury
Selenium
Silver
Zinc

APPENDIX B

Details on Fish Ingestion Rate from Veritas 2017 Memo

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Memorandum

To: Mark Harris, Liz Mittal, Enrique Castro, and Carlie Thompson

From: Jason C. Kinnell, Matthew F. Bingham, Sara G. Hickman, and Victoria L. MacPherson

Date: June 6, 2017

Subject: Newark Bay Fish and Crab Ingestion Estimates

This memo summarizes Veritas Economic Consulting's (Veritas) efforts to develop fish and crab ingestion estimates for Newark Bay using available data. The available data come from the following sources of fishing and crabbing in and around the Newark Bay Complex:

- 1995 Newark Bay Complex Fishing and Crabbing Survey reported in Pflugh et al. (1999) and (2011);
- 2000 New Jersey Outdoor Recreation Survey reported in Kinnell et al. (2006) and Bingham et al. (2011); and
- 2013 New Jersey Outdoor Recreation Survey reported in Bingham et al. (2014) and Kinnell and Bingham (2014).

Veritas used two different evaluation methods to develop Newark Bay fish and crab ingestion estimates from these data sources:

- Evaluation 1 – Estimates Newark Bay fish and crab ingestion using the sample data from the 1995 Newark Bay Complex Fishing and Crabbing Survey (1995 NBC Survey). This evaluation method is designed to replicate the fish and crab ingestion estimates that have been reported in the literature based on data from the 1995, 1999, 2002, and 2005 Newark Bay Complex Fishing and Crabbing Surveys as reported in Pflugh et al. (1999), Burger (2002), and Pflugh et al. (2011).[1]
- Evaluation 2 – The results in Evaluation 1 are estimated for only the sample of anglers that were interviewed during the 1995 Newark Bay Complex Fishing and Crabbing Survey. Because the results are not weighted to the angling population taking trips to Newark Bay, they apply only

[1] Veritas has the data for the 1995 Newark Bay Complex Fishing and Crabbing Survey, but does not have the 1999, 2002, or 2005 surveys. If the data from the 1999, 2002, and/or 2005 Newark Bay Complex Fishing and Crabbing Surveys can be obtained, Veritas can incorporate this data into the analysis. However, as the results presented later in this memorandum show, the ingestion estimates developed in Evaluation 1 using the 1995 Newark Bay Complex Fishing and Crabbing Survey are very similar to the consumption estimates presented in Burger (2002) and the U.S. EPA's Technical Memorandum *Fish and Crab Consumption Estimates for the LPRSA Human Health Risk Assessment* (USEPA 2012).

to the interviewed sample and not to the entire angling population. Evaluation 1 presents the unweighted, sample results to provide direct comparison to ingestion rates presented in the literature using data from both the 1995 and the 1999 survey of Newark Bay Complex anglers. Because the results in the literature are unweighted, they can be directly compared with Evaluation 1. However, to be representative of the actual angling population taking trips to Newark Bay, the sample data have to be weighted to the angling population. Evaluation 2 accomplishes this by expanding Evaluation 1's analysis to place the sample data in the context of the entire angling population taking trips to Newark Bay. Evaluation 2 uses data and analysis from two additional surveys to develop ingestion estimates for the entire population of Newark Bay Complex anglers: the 2000 and 2013 New Jersey Outdoor Recreation Surveys. These two surveys collected data from the households that are most likely to have anglers that take trips to the Newark Bay Complex—anglers residing in the five counties surrounding the Newark Bay Complex (Union, Essex, Hudson, Bergen and Passaic Counties—herein referred to as the Five County Area). Kinnell et al. (2006) and Bingham et al. (2011) present the analysis and results of the 2000 New Jersey Outdoor Recreation Survey data, and Bingham et al. (2014) and Kinnell and Bingham (2014) present the analysis and results of the 2013 New Jersey Outdoor Recreation Survey data.

The analysis of the data from these surveys also provides the ability to develop models of anglers' trip taking preferences referred to as angler preference functions. These angler preference functions provide the ability to characterize how angler behavior would change as various site characteristics change. Because baseline risk has to assess what ingestion would be if all site conditions were the same as current conditions, but no sign was present at the site advising anglers not to consume fish or crabs from the site, the angler preference functions provide the ability to simulate baseline risk conditions and determine how many more trips anglers would take to the Newark Bay Complex and how many more fish and/or crabs they would consume. Evaluation 2, therefore, not only develops the ingestion estimates for the entire angling population, but develops these estimates under current and baseline risk conditions, whereas Evaluation 1 only estimates ingestion for the sample of interviewed anglers under current conditions.

Table 1 compares the results from each of the evaluation alternatives. The table separates the comparison into two geographic areas and conditions:

- estimates developed for anglers taking trips to sites on Newark Bay under current and baseline risk conditions, labeled Newark Bay Sites – Current and Baseline Risk Conditions and

- estimates for anglers taking trips to sites in the entire Newark Bay Complex under current risk conditions labeled Newark Bay Complex – Current Risk Conditions (sites in the Newark Bay Complex include sites on the Passaic and Hackensack Rivers, the Arthur Kill, Kill van Kull, and Newark Bay).

Table 1
Comparison of Consumption by Newark Bay Complex Anglers and Crabbers

	Newark Bay Sites – Current and Baseline Risk Conditions						Newark Bay Complex – Current Risk Conditions					
	All Anglers Fish & Crab (F&C)			Consuming Anglers/Crabbers Fish & Crab (F&C)			All Anglers	Consuming Anglers/Crabbers				
									Burger 2002			EPA TDD Burger 2002 Fish Only
Estimates	Eval 1 Current	Eval 2 Current	Eval 2 Baseline	Eval 1 Current	Eval 2 Current	Eval 2 Baseline	Eval 1 F&C	Eval 1 F&C	Crab Only	Fish Only	F&C	
Anglers	57	2,439	3,550	29	1,193	1,833	276	130	110	111	33	61
Trips	57	12,190	21,130	29	7,938	14,665	276	130	110	111	33	61
Mean (g/day)	9.87	1.78	3.07	19.40	3.63	5.95	8.01	17.01	15.78	22.56	54.33	13.0
50^{th} Percentile (g/day)	0.86	0.00	0.36	5.72	1.77	2.27	0.00	5.56	—	—	—	3.7
90^{th} Percentile (g/day)	24.19	5.13	8.47	45.10	9.04	15.76	16.01	37.20	—	—	—	37.3
95^{th} Percentile (g/day)	45.10	8.92	16.14	85.22	13.73	24.09	31.82	83.52	—	—	—	62.9
99^{th} Percentile (g/day)	85.22	21.10	39.61	126.73	27.12	48.48	124.35	127.89	—	—	—	—

The table presents estimates for the Newark Bay Complex in addition to Newark Bay because the Newark Bay Complex estimates are the ones presented in the literature and available for comparison. The first column identifies the various estimates that are presented in the table: the number of anglers used in each evaluation, the number of trips they take, and the ingestion percentiles presented in grams per day. In addition to presenting the results for each evaluation alternative, the table also presents the estimates for two different population types: all anglers and consuming anglers. This comparison allows for evaluating the sensitivity of the estimates to the population specification.

The results presented for each estimate under the Newark Bay Sites – Current and Baseline Risk Conditions heading illustrates the differences between Evaluations 1 and 2. Because Evaluation 1 develops the ingestion estimates for only the sample of anglers that were interviewed during the survey (i.e., the estimates apply to the interviewed anglers and not to the entire angling population), it represents the estimates for the 57 anglers interviewed on 57 trips during the 1995 NBC Survey and the 29 of those anglers that consume fish and/or crab from Newark Bay. Evaluation 1 can also only provide these estimates under current risk conditions.

By comparison, Evaluation 2 places the information from the 1995 NBC Survey in the context of the entire angling population taking trips to Newark Bay sites under both current and baseline risk conditions. As the table shows, Evaluation 2 estimates that approximately 2,500 anglers take 12,190 trips to sites in Newark Bay. Of these, 1,193 of the anglers consume fish and/or crab from Newark Bay and take 7,938 trips. Because Evaluation 2 can also evaluate behavior under baseline risk conditions, it has the ability to estimate how many more anglers may take trips to sites in Newark Bay, how many more trips they make take, how many more fish and/or crab they may catch, and how many more fish and/or crabs they may consume. The estimates under the Evaluation 2 Baseline headings present these results. As the table shows, under baseline risk conditions, the angling population taking trips to sites in Newark Bay is estimated to increase to 3,550 anglers taking 21,130 trips. Of these, 1,833 of the anglers consume fish and/or crabs and take 14,665 trips.

By comparing the results of Evaluations 1 and 2, the table illustrates the implication of what happens to the ingestion estimates when they are placed in both the population and the baseline risk context. When the estimates are developed over the entire angling population, the mean ingestion under current conditions decreases from 9.87 g/day using just the 1995 NBC Survey data (Evaluation 1) to 1.78 g/day under current conditions and 3.07 g/day under baseline risk conditions (Evaluation 2). The same pattern holds for each of the reported ingestion percentiles as well as when the analysis develops the estimates for consuming anglers only.

The second half of the table, labeled Newark Bay Complex – Current Risk Conditions, presents the results when the data from all the sites surveyed during the 1995 NBC Survey are used to develop the ingestion rates. This portion of the table presents the estimates for Evaluation 1 only because it provides a comparison between the ingestion estimates using only the 1995 NBC Survey data and the estimates provided in the literature using the 1999 NBC Survey data.[2] As the table shows, using all of the 1995 NBC Survey data expands the data from 57 total anglers and 29 consuming anglers interviewed at Newark Bay sites to 276 anglers and 130 consuming anglers interviewed at sites throughout the Newark Bay Complex. When the analysis is expanded to include the Newark Bay Complex survey data, while similar, the ingestion estimates are lower than those for the Newark Bay sites only, except for the 99th

[2] While there are two additional angler surveys conducted in the Newark Bay Complex in 2002 and 2005, Pflugh et al. (2011) does not present the ingestion estimates developed from these studies; Pflugh et al. (2011) only present the risk estimates they developed using the 2002 and 2005 survey data.

percentile which is higher. This is the case when the analysis is conducted using all anglers and consuming anglers only.

The final four columns of Table 1 present the comparative ingestion estimates from the literature. The three columns labeled Burger 2002 present estimates that Burger (2002) presented using data from the 1999 survey of Newark Bay Complex anglers and crabbers. The final column, labeled EPA TDD Burger 2002, presents ingestion estimates that EPA developed in its Technical Development Document (TDD) (USEPA 2012) using the data presented in Burger (2002). Because Veritas does not have the data from the 1999 Newark Bay Complex survey, we present these estimates for comparison to the estimates we developed from the 1995 NBC Survey using Evaluation 1. The mean ingestion estimate for crab consumers and fish consumers presented in Burger (2002) and in EPA's Technical Development Document are all similar to the mean ingestion estimate developed from the 1995 NBC Survey data using Evaluation 1: 17.01 g/day for Evaluation 1 versus 15.78 for crab anglers and 22.56 for fish anglers from Burger (2002) and 18.0 from EPA's TDD. In addition, the 50th, 90th, and 95th percentile estimated for consuming anglers from EPA's Technical Development Document is similar to the same percentiles estimated from the 1995 NBC Survey data using Evaluation 1. These similarities suggest that while Veritas does not have the data from the 1999 survey, their inclusion would not cause meaningful differences in the ingestion estimates from what we have developed using the 1995 NBC Survey data.

The remainder of this memo provides an overview of Evaluations 1 and 2 and the resulting ingestion estimates for anglers taking trips to Newark Bay.

Evaluation 1

Evaluation 1 uses the sample data from the 1995 NBC Survey. The survey asked respondents about consumption behavior for blue crab, striped bass, bluefish, white catfish, white perch, and American eel. Specifically, the survey asked how often the respondent or members of the household ate fish or crab caught from the Newark Bay Complex. The respondent was given a choice of every day, 2 to 3 times per week, once a week, twice a month, once a month, or less than once a month. The respondent then stated about how much of the species he/she and each member of the household ate at one meal. For blue crab, respondents were asked the number of blue crab. For the fish species, respondents were asked to report the typical serving size per meal.

Evaluation 1 uses responses for these two questions for anglers that were interviewed at sites on Newark Bay (57 anglers) to estimate ingestion. Where portion size was given, the evaluation used this as the consumption per meal. If the number of fish is provided, the evaluation uses data from Windward (2010; 2011) or stock dynamic models to estimate a distribution of the weight by species, as well as a distribution of edible portion. For blue crab, Evaluation 1 uses a distribution of edible mass, with a mean of 40.5 grams from Pflugh et al. (2011). Multiplying the edible mass by the number of fish or crab eaten per meal returns the grams consumed per meal. Multiplying the grams per meal by the number of meals per month estimates the grams consumed per month.

The 1995 NBC Survey does not ask the number of months out of the year that respondents eat locally-caught fish or crab. The 2002 and 2005 NBC crabbing surveys include this question (Pflugh et al., 2011). Pflugh et al. (2011) states that respondents consume self-caught crab 32 percent of the year (approximately 4 months). Because fishing season is generally longer than crabbing season, Evaluation 1 uses a distribution of 1 to 6 consuming months per year with an average of 4 months.

Table 2 presents the results of Evaluation 1 ingestion estimates for Newark Bay. The table presents the mean, median, 90th, 95th, and 99th percentiles for all species, all fish species, and by species.[3] Ingestion is estimated across the following different populations presented in the second column: All anglers, All Consuming Anglers, and Consumers of the corresponding species. The third column provides the number of anglers the analysis uses in each consuming scenario. There are 57 Newark Bay anglers. Twenty-nine of these anglers consume fish and/or crab. Of the 29 consumers, one respondent reported consuming American eel, all 29 reported consuming blue crab, and two reported consuming striped bass. The fourth column and its sub-columns present ingestion in grams per day. The mean and each percentile include the 90-percent confidence interval developed for each estimate.

As Table 2 indicates, the mean consumption for the 57 anglers is 9.87 g/day and the 95th percentile is 45.10 g/day. This column includes 28 anglers who are catch and release anglers. The mean consumption for the 29 consuming anglers in Evaluation 1 is 19.40 g/day and the 95th percentile is 85.22 g/day.

For Evaluation 1, blue crab makes up over 96 percent of the mean ingestion estimates at 9.53 g/day (all anglers) and 18.74 g/day (consuming anglers). The one respondent who consumes American eel consumes an average of 0.59 g/day. Consumers of blue crab consume an average of 18.74 g/day and the 95th percentile level is 82.95 g/day. Consumers of striped bass consume an average of 9.31 g/day and the 95th percentile level is 17.47 g/day.

[3] Respondents interviewed at Newark Bay sites did not report consuming bluefish, white perch, or white catfish. Therefore, these species are excluded from Table 1. The All Fish Species ingestion rates include American eel and striped bass.

Table 2
Newark Bay Ingestion Estimates by Scenario—Evaluation 1

Species Scenario	Angling Population Scenario	Anglers	Consumption (g/day)				
			Mean	Median	90th	95th	99th
All Species	All Anglers	57	9.87 (2.71-21.32)	0.86 (0.23-1.87)	24.19 (6.42-52.47)	45.10 (12.29-94.67)	85.22 (22.65-183.10)
	All Consuming Anglers	29	19.40 (5.33-41.91)	5.72 (1.71-12.29)	45.10 (12.29-94.67)	85.22 (22.65-183.10)	126.73 (33.84-270.23)
All Fish Species	All Anglers	57	0.34 (0.06-1.31)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	1.14 (0.58-1.65)
	All Consuming Anglers	29	0.66 (0.11-2.58)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	1.14 (0.58-1.65)	18.06 (2.64-73.81)
	Fish Consumers	2	9.60 (1.67-37.46)	1.14 (0.58-1.65)	18.06 (2.64-73.81)	18.06 (2.64-73.81)	18.06 (2.64-73.81)
American eel	All Anglers	57	0.01 (0.001-0.04)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)
	All Consuming Anglers	29	0.02 (0.001-0.07)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.59 (0.04-2.08)
	American eel Consumers	1	0.59 (0.04-2.08)	0.59 (0.04-2.08)	0.59 (0.04-2.08)	0.59 (0.04-2.08)	0.59 (0.04-2.08)
Blue crab	All Anglers	57	9.53 (2.53-20.68)	0.86 (0.23-1.87)	24.19 (6.42-52.47)	41.48 (11.01-89.95)	82.95 (22.01-179.91)
	All Consuming Anglers	29	18.74 (4.97-40.67)	5.67 (1.50-12.29)	41.48 (11.01-89.95)	82.95 (22.01-179.91)	124.43 (33.02-269.86)
	Blue crab Consumers	29	18.74 (4.97-40.67)	5.67 (1.50-12.29)	41.24 (11.37-83.91)	82.95 (22.01-179.91)	124.43 (33.02-269.86)
Striped bass	All Anglers	57	0.33 (0.05-1.31)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	1.14 (0.58-1.65)
	All Consuming Anglers	29	0.64 (0.11-2.58)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	1.14 (0.58-1.65)	17.47 (2.45-73.78)
	Striped bass Consumers	2	9.31 (1.55-37.35)	1.14 (0.58-1.65)	17.47 (2.45-73.78)	17.47 (2.45-73.78)	17.47 (2.45-73.78)

Evaluation 2

The results for Evaluation 1, and the relevant comparative estimates in the literature, are sample estimates, meaning they are developed for the sample of respondents interviewed from the survey and are not extrapolated to the overall angling population that takes trips to Newark Bay. If the sample data is not representative of the population's behavior, then the sample estimates will not be an accurate estimate of the population. Evaluation 2 expands the results from Evaluation 1 and places the sample data in the context of the overall angler population that takes fishing and crabbing trips to Newark Bay. Evaluation 2's analysis fuses ZIP-Code-level population data from the Five County Area with a preference function of angler behavior estimated for Five County Anglers using data from the 2013 and 2000 New Jersey Outdoor Recreation Surveys (NJORS). The preference function, presented in Bingham et al. (2011) and (2014), identifies how much the characteristics of fishing sites affect how many trips anglers take to those sites.[4] For example, when anglers take a trip, they have a choice of which site to

[4] See Bingham et al. (2014) for a detailed discussion on the 2013 New Jersey Outdoor Recreation Survey and the estimation of the angler preference function used in this analysis; see Bingham et al. (2011) and Kinnell et al. (2006) for a detailed discussion of the 2000 New Jersey Outdoor Recreation Survey

visit. The sites from which they can choose have numerous characteristics, such as the distance from their home, the number of fish they expect to catch, facility amenities (e.g., presence of a boat launch), and waterbody characteristics and surroundings (e.g., presence of a fish-consumption advisory, level of industrialization, and crime rates). The preference function estimates the importance that anglers place on each of these characteristics when they decide where to go fishing and how many trips to take. Bingham et al. (2011) and (2014) estimates the preference function for Five County Area anglers using random utility maximization (RUM) modeling.

The demographic profiles and predicted trips to Newark Bay estimated using the preference function are calibrated with the angler population's demographics as observed from the 1995 NBC Survey and anglers who stated visiting Newark Bay sites from the 2000 and the 2013 NJORS. The calibration variables are designed to adjust the visitation rates by demographic profile of the predicted anglers using the 2010 Census demographics, so that the demographic profile of the anglers predicted at each site matches the demographic profile observed from the 1995 NBC Survey and the 2000 and 2013 NJORS.

To develop ingestion estimates, the analysis uses the edible mass by species from Evaluation 1. A statistical model is estimated using the 1995 NBC data and data from the 2013 NJORS to examine the relationship between demographics and kept catch and demographics and consuming behavior. The species composition is averaged across the two surveys and applied to the predicted number of fish kept by demographic group to estimate the predicted number of each species kept by each demographic group. The number of kept species is then multiplied by the edible mass per species to calculate the grams consumed per trip by each demographic group.

This grams per trip estimate is applied to an estimate of trip frequency distribution to calculate current consumption estimates. The trip frequency distribution is estimated for consumers and non-consumers based on responses about trip-taking behavior to the Complex from the 2013 NJORS. The breakdown of consumers to non-consumers is estimated from the 1995 NBC data and the 2013 NJORS.

In addition to developing trip and consumption estimates under current risk conditions, Evaluation 2 estimates changes in trips and consumption under baseline risk conditions. The baseline risk consumption estimates use changes in behavior data from the 2013 NJORS. The 2013 NJORS provides the data needed to develop baseline trips and increases in consumption by species and Angler Type. Specifically, respondents state whether they are aware of the advisory. If they are aware of the advisory, respondents then state whether they would increase trips to the waterbody and/or increase consumption under baseline risk conditions.

Table 3 presents the results of Evaluation 2 ingestion estimates for Newark Bay. The table presents the statistics on the angling population and the mean, median, 90th, 95th, and 99th percentile for all species by all anglers and by consuming anglers under current and baseline risk conditions. Table 3 also presents the ingestion estimates for each species. As Table 3 indicates, under current conditions, there are 2,439 anglers taking 12,190 trips to Newark Bay. Almost 1,200 of these anglers consume fish and/or crabs. These consumers take 7,938 trips to Newark Bay. The mean consumption for all anglers under current conditions is 1.78 g/day and the 95th percentile is 8.92 g/day. The mean consumption for consuming anglers under current conditions is 3.63 g/day and the 95th percentile is 13.73 g/day.

Under baseline risk conditions, 3,550 anglers are estimated to take over 21,000 trips to Newark Bay. Almost 1,850 of these anglers are consumers. These consumers are estimated to take 14,665 trips to Newark Bay. Under baseline conditions, the mean consumption for all anglers is 3.07 g/day and the 95th percentile is 16.14 g/day. The mean consumption for consuming anglers under current conditions is 5.95 g/day and the 95th percentile is 24.09 g/day.

The table then presents the estimates for all fish species (excluding crab) and for each individual species.

Table 3
Newark Bay Ingestion Estimates by Scenario—Evaluation 2

Species Scenario	Angling Population: Scenario	Number of Anglers	Trips	Risk Estimate Scenario	Consumption (g/day): Mean	Median	90th	95th	99th
All Species	All Anglers	3,550	21,130	Baseline	3.07 (1.08-6.54)	0.36 (0.10-0.80)	8.47 (2.99-18.18)	16.14 (5.49-35.55)	39.61 (13.76-79.84)
		2,439	12,190	Current	1.78 (0.69-4.43)	0.00 (0.00-0.00)	5.13 (2.00-12.48)	8.92 (3.40-21.47)	21.10 (8.28-53.54)
	All Consuming Anglers	1,833	14,665	Baseline	5.95 (2.09-12.73)	2.27 (0.80-4.82)	15.76 (5.30-35.01)	24.09 (7.99-53.33)	48.48 (16.78-97.76)
		1,193	7,938	Current	3.63 (1.40-9.06)	1.77 (0.70-4.42)	9.04 (3.49-22.17)	13.73 (5.19-34.89)	27.12 (10.40-68.17)
All Fish Species[a]	All Anglers	3,550	21,130	Baseline	1.82 (0.41-5.10)	0.24 (0.10-0.70)	5.11 (1.20-14.22)	9.46 (2.00-26.63)	22.50 (4.99-69.07)
		2,439	12,190	Current	1.08 (0.24-3.12)	0.00 (0.00-0.00)	3.13 (0.70-8.86)	5.43 (1.20-15.51)	12.92 (2.80-37.65)
	All Consuming Anglers	1,833	14,665	Baseline	3.53 (0.79-9.87)	1.49 (0.40-4.22)	9.23 (2.00-26.44)	13.83 (3.09-40.16)	28.03 (6.18-77.46)
		1,193	7,938	Current	2.22 (0.48-6.38)	1.07 (0.20-3.12)	5.52 (1.20-15.70)	8.33 (1.80-24.17)	16.52 (3.60-48.69)
	Fish Consumers	1,825	14,599	Baseline	3.54 (0.81-9.87)	1.50 (0.40-4.22)	9.24 (2.00-26.44)	13.84 (3.09-40.16)	28.04 (6.19-77.46)
		1,176	7,827	Current	2.22 (0.54-6.38)	1.08 (0.30-3.12)	5.53 (1.30-15.70)	8.35 (1.90-24.17)	16.53 (3.80-48.69)
American eel	All Anglers	3,550	21,130	Baseline	0.01 (0.00-0.05)	0.00 (0.00-0.00)	0.04 (0.00-0.10)	0.08 (0.00-0.21)	0.18 (0.00-0.60)
		2,439	12,190	Current	0.01 (0.00-0.18)	0.00 (0.00-0.00)	0.01 (0.00-0.10)	0.03 (0.00-0.10)	0.09 (0.00-0.30)
	All Consuming Anglers	1,833	14,665	Baseline	0.03 (0.00-0.09)	0.01 (0.00-0.10)	0.08 (0.00-0.21)	0.12 (0.00-0.40)	0.25 (0.00-0.71)
		1,193	7,938	Current	0.01 (0.00-0.04)	0.002 (0.00-0.00)	0.03 (0.00-0.10)	0.05 (0.00-0.20)	0.12 (0.00-0.31)
	American eel Consumers	268	2,147	Baseline	0.12 (0.00-0.18)	0.10 (0.10-0.10)	0.18 (0.10-0.40)	0.22 (0.10-0.51)	0.36 (0.10-1.01)
		80	530	Current	0.08 (0.00-0.14)	0.10 (0.10-0.10)	0.13 (0.10-0.21)	0.16 (0.10-0.30)	0.21 (0.10-0.50)
Blue crab	All Anglers	3,550	21,130	Baseline	1.38 (0.33-3.72)	0.12 (0.00-0.30)	3.80 (0.90-9.13)	7.58 (1.69-20.03)	19.17 (4.64-56.69)
		2,439	12,190	Current	0.69 (0.19-1.46)	0.00 (0.00-0.00)	1.98 (0.60-4.11)	3.45 (0.10-7.30)	8.24 (2.30-17.62)
	All Consuming Anglers	1,833	14,665	Baseline	2.68 (0.64-7.20)	0.85 (0.20-1.92)	7.41 (1.69-19.55)	11.53 (2.48-30.73)	23.03 (5.19-63.83)
		1,193	7,938	Current	1.41 (0.39-2.99)	0.68 (0.20-1.41)	3.49 (1.00-7.31)	5.29 (1.50-11.11)	10.58 (2.90-22.05)
	Blue crab Consumers	1,791	14,332	Baseline	2.70 (0.72-7.20)	0.86 (0.30-1.92)	7.45 (1.79-19.55)	11.57 (2.69-30.73)	23.18 (5.76-63.83)
		1,169	7,776	Current	1.42 (0.46-2.99)	0.68 (0.20-1.41)	3.50 (1.10-7.31)	5.31 (1.60-11.11)	10.59 (3.00-22.05)

Table 3, continued

Species Scenario	Angling Population: Scenario	Number of Anglers	Trips	Risk Estimate Scenario	Consumption (g/day): Mean	Median	90th	95th	99th
Bluefish	All Anglers	3,550	21,130	Baseline	1.16 (0.21-3.01)	0.16 (0.00-0.40)	3.20 (0.60-8.41)	5.91 (1.1-15.51)	14.53 (2.59-39.54)
		2,439	12,190	Current	0.66 (0.13-1.75)	0.00 (0.00-0.00)	1.89 (0.40-5.01)	3.31 (0.70-8.71)	7.93 (1.60-22.01)
	All Consuming Anglers	1,833	14,665	Baseline	2.24 (0.41-5.82)	0.94 (0.20-2.60)	5.74 (1.10-15.11)	8.56 (1.50-22.81)	18.11 (3.29-50.03)
		1,193	7,938	Current	1.35 (0.27-3.59)	0.65 (0.10-1.60)	3.35 (0.70-8.72)	5.06 (1.00-13.31)	10.20 (2.0-27.87)
	Bluefish Consumers	1,786	14,287	Baseline	2.26 (0.47-5.82)	0.95 (0.20-2.60)	5.78 (1.20-15.11)	8.59 (1.70-22.81)	18.16 (3.29-50.03)
		1,133	7,538	Current	1.37 (0.35-3.59)	0.66 (0.20-1.60)	3.37 (0.80-8.72)	5.09 (1.20-13.31)	10.23 (2.10-27.87)
Striped bass	All Anglers	3,550	21,130	Baseline	0.67 (0.07-2.52)	0.07 (0.00-0.21)	1.95 (0.20-7.21)	3.55 (0.40-13.79)	7.76 (0.80-32.45)
		2,439	12,190	Current	0.49 (0.04-1.49)	0.00 (0.00-0.00)	1.49 (0.10-4.27)	2.56 (0.20-7.67)	5.49 (0.60-17.71)
	All Consuming Anglers	1,833	14,665	Baseline	1.31 (0.13-4.88)	0.58 (0.10-1.93)	3.49 (0.30-13.29)	5.10 (0.50-18.92)	9.04 (1.00-37.01)
		1,193	7,938	Current	1.01 (0.09-3.05)	0.53 (0.00-1.56)	2.60 (0.20-7.77)	3.78 (0.40-11.48)	6.69 (0.70-21.72)
	Striped bass Consumers	1,429	11,433	Baseline	1.37 (0.22-4.88)	0.60 (0.10-1.93)	3.59 (0.40-7.77)	5.22 (0.70-18.92)	9.22 (1.2-37.01)
		833	5,546	Current	1.08 (0.19-3.05)	0.55 (0.10-1.56)	2.70 (0.50-13.29)	3.89 (0.50-11.48)	0.60 (0.90-21.72)
White perch	All Anglers	3,550	21,130	Baseline	0.05 (0.02-0.10)	0.00 (0.00-0.00)	0.15 (0.00-0.10)	0.27 (0.10-0.51)	0.63 (0.20-0.60)
		2,439	12,190	Current	0.02 (0.01-0.05)	0.00 (0.00-0.00)	0.09 (0.10-0.30)	0.14 (0.10-0.20)	0.32 (0.30-1.31)
	All Consuming Anglers	1,833	14,665	Baseline	0.10 (0.02-0.09)	0.04 (0.00-0.00)	0.26 (0.10-0.51)	0.39 (0.10-0.40)	0.80 (0.20-0.80)
		1,193	7,938	Current	0.05 (0.05-0.19)	0.004 (0.00-0.10)	0.14 (0.10-0.20)	0.02 (0.20-0.90)	0.43 (0.40-1.70)
	White perch Consumers	854	6,834	Baseline	0.20 (0.12-0.20)	0.11 (0.10-0.10)	0.38 (0.20-0.40)	0.55 (0.30-0.91)	1.04 (0.60-1.82)
		353	2,350	Current	0.15 (0.14-0.30)	0.10 (0.10-0.20)	0.26 (0.20-0.70)	0.37 (0.20-0.60)	0.60 (0.40-1.00)

[a] The All Fish Species ingestion rates include American eel, bluefish, striped bass, and white perch.

References

Bingham, M.F., Z. Li, K.E. Mathews, C. Spagnardi, J. Whaley, S. Veale, and J. Kinnell. 2011. "An Application of Behavioral Modeling to Characterize Urban Angling Decisions and Values." *North American Journal of Fisheries Management* 31:257–268.

Bingham, M.F., S.G. Veale, Z. Li, G.S. Crownfield, D.M. Woodard, and J.C. Kinnell. 2014. "Integrating Revealed and Stated Preference Data to Improve the Estimation of Baseline Risk Fish Ingestion." Working Paper No. 2014-03. Available at http://www.veritaseconomics.com/Working%20Papers/Bingham.et.al.2014.Integrating.RP.and.SP.Data.to.Improve.Estimation.of.Baseline.Risk.Fish.Ingestion.pdf

Burger, J. 2002. "Consumption Patterns and Why People Fish." *Environ Res A* 90:125–135.

Kinnell, J.C., M.F. Bingham, A.F. Mohamed, W.H. Desvousges, T.B. Kiler, E.K. Hastings, and K.T. Kuhns. 2006. "Estimating Site-Choice Decisions for Urban Recreators." *Land Economics* 82(2):257–272.

Kinnell, Jason C. and Matthew F. Bingham. 2014. "Developing Baseline Risk Fish Ingestion Estimates for Baseline Human Health Risk Assessments." Technical Working Paper. Veritas Economic Consulting. Cary, NC. Available at http://www.veritaseconomics.com/Working%20Papers/Kinnell.and.Bingham.2014.Developing.Baseline.Risk.Fish.Ingestion.Estimates.pdf.

Pflugh, K., L. Lurig, L. Von Hagen, S. Von Hagen, and J. Burger. 1999. "Urban Anglers' Perception of Risk from Contaminated Fish." *Science of the Total Environment* 228:203–218.

Pflugh, Kerry Kirk, Alan H Stern, Laura Nesposundy, Lynette Lurig, Bruce Ruppel, and Gary A. Buchanan. 2011. "Consumption Patterns and Risk Assessment of Crab Consumers from the Newark Bay Complex, New Jersey, USA." *Science of the Total Environment* (2011).

USEPA. 2012. Technical Memorandum *Fish and Crab Consumption Rates for the LPRSA Human Health Risk Assessment*. February 2, 2012. U.S. Environmental Protection Agency, Region 2, New York, NY.

Windward. 2010. *Fish and Decapod Field Report for the Late Summer/Early Fall 2009—Draft*. Prepared for Cooperating Parties Group Newark, NJ. Seattle, WA: Windward Environmental, LLC.

Windward. 2011. *2009 Fish and Blue Crab Chemistry Data for the Lower Passaic River Study Area.* Prepared for Cooperating Parties Group Newark, NJ. Seattle, WA: Windward Environmental, LLC.